7. SEISMIC INTERACTION

7.1 INTRODUCTION[1]

The purpose of this section is to describe seismic interaction and techniques for evaluating its effects on equipment in DOE facilities. Seismic interaction is the physical interaction of any structures, piping, or equipment with a nearby item of equipment caused by relative motions from an earthquake. Components with fragile appendages (such as instrumentation tubing, air lines, and glass site tubes) are most prone to damage for seismic interaction. An inspection should be performed in the area adjacent to and surrounding equipment to identify any seismic interaction condition which could adversely affect the capability of the equipment to perform its intended function.

An overview of seismic interaction is shown in Figure 7.1-1. An earthquake can cause various types of interactions such as bumping, falling, or flooding. The SCEs should identify the various types of interactions and work with other SRT members to determine the overall effect on the facility. This chapter describes the seismic interaction effects covered by the DOE Seismic Evaluation Procedure and how they can be evaluated. The seismic interaction effects which are included within the scope of this procedure are proximity; structural failure and falling; flexibility of attached lines and cables and differential displacements; and water spray, flood, and fire hazards.

Using this chapter, the SCEs should be familiar with the various types of interaction, be able to judge if an interaction is credible and its significance during a walkdown, be able to identify outliers, and be familiar with DOE Guidance related to seismic interactions.

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[1] Based on Section D.1 of SQUG GIP (Ref. 1)

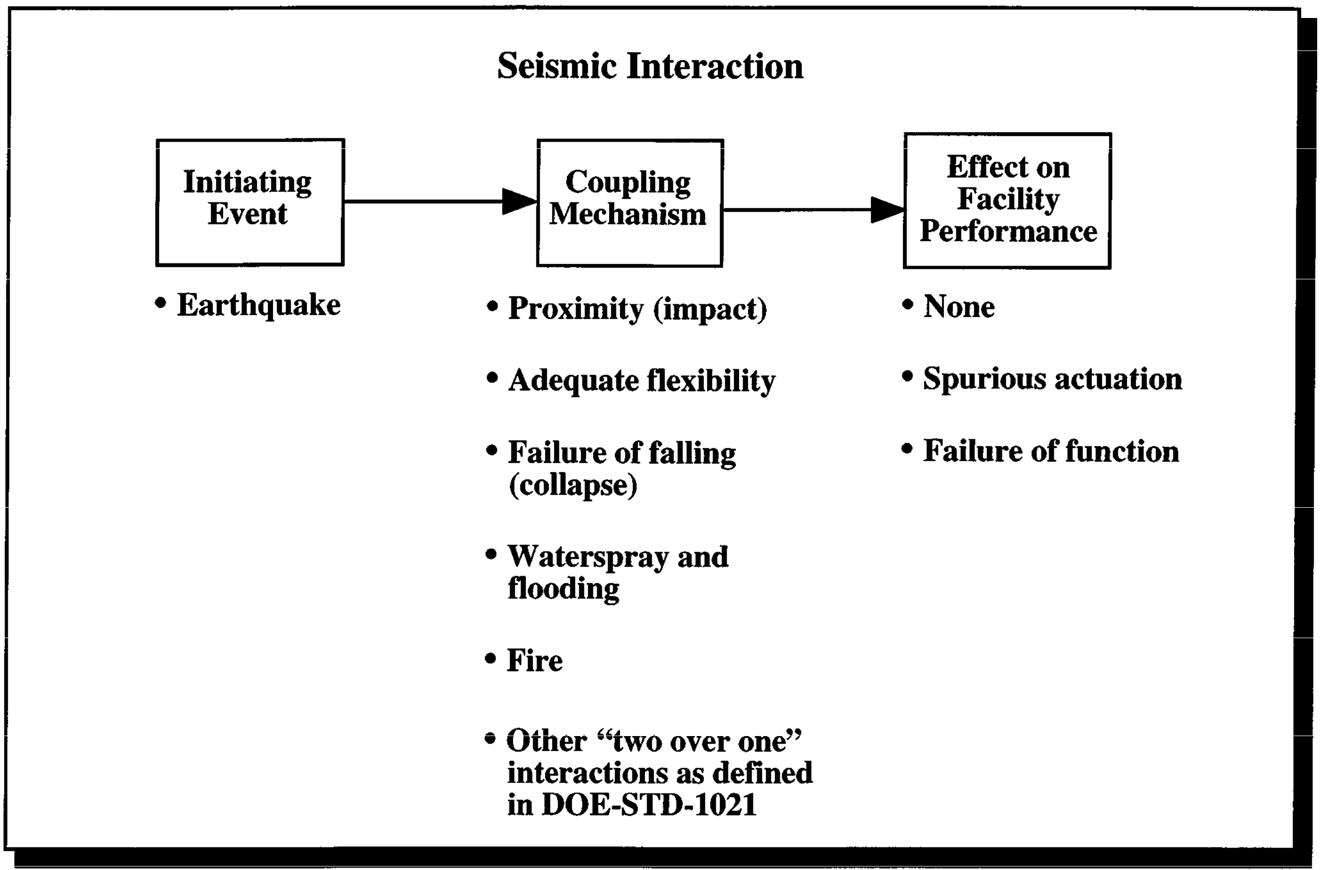

Figure 7.1-1 Overview of Seismic Interaction

7.2 INTERACTION EFFECTS

An example of the effects of seismic interaction is shown in Figure 7.2-1. The hanging conduit or piping, which is free to swing during earthquake motion, is the source, while the target is the electrical cabinet. The shaded zone in the figure defines the zone of influence where the source can affect the target. For a credible interaction to occur, the source must impact or interact with the target (see Figure 7.2-2). While evaluating the effects of credible seismic interactions, the SCEs must determine if the interactions are significant or not. The screening process for interaction effects includes evaluating the target, source, credibility, and significance. If all of these screens or considerations are satisfied, then the interaction being evaluated is an outlier and should be resolved as discussed in Chapter 12.

A significant interaction will compromise the intended performance and will affect the safety function of the equipment being evaluated. Examples of a significant interaction include an air-operated valve impacting a nearby structural column (see Figure 7.2-3), rupture of water sprinkler piping above medium-voltage switchgear, or a cart impacting a motor control center which contains vibration sensitive equipment such as essential relays.

A non-significant interaction, on the other hand, will not cause appreciable damage to the equipment being evaluated. Examples of a non-significant interaction include a light weight object impacting a large diameter conduit (see Figure 7.2-4) or small diameter piping impacting the outside casing of a rugged horizontal pump.

7.2.1 Proximity[2]

Seismic interaction due to proximity is the impact of adjacent equipment or structures on equipment due to their relative motion during seismic excitation. This relative motion can be the result of the vibration and movement of the equipment itself or any adjacent equipment or structures. When sufficient anchorage, bracing, adequate clearance, or other means are provided to preclude large deflections, seismic proximity effects are not typically a concern.

Even if there is impact between adjacent equipment or structures, there may not be any significant damage to the equipment. In such cases, this seismic interaction would not be considered a reason for concern, provided the equipment can still accomplish its intended function. One exception to this is electrical cabinets containing essential relays which are required to function. Since relays are susceptible to chatter, any impact on an electrical cabinet which has such an essential relay in it should be considered an unacceptable seismic interaction and cause for identifying that electrical cabinet as an outlier.

Examples of potential seismic interaction due to proximity include the following:

- Equipment carts, dollies, chains, air bottles, welding equipment, etc., may roll into, slide, overturn, or otherwise impact equipment
- Electrical cabinets that deflect and impact walls, structural members, another cabinet, etc., may damage devices in the cabinet or cause devices to trip or chatter
- Storage cabinets, office cabinets, files, bookcases, wall lockers, and medicine cabinets may fall or tip into equipment

[2] Based on Sections D.2 and D.6 of SQUG GIP (Ref. 1)

- The doors on electrical cabinets may swing and impact devices or cause relays to chatter.
- Inadequately anchored or braced equipment such as pumps, vessels, tanks, heat exchangers, cabinets, and switchgear may deflect or overturn and impact equipment

The judgment of the SCEs should be used to differentiate between credible and non-credible interaction hazards.

7.2.1.1 Piping, Raceways, and Ductwork Deflections[3]

The motion of piping, conduit, cable raceways, and other distribution lines may result in impact interactions with equipment being reviewed. Non-safety-related piping is commonly supported with rod hangers or other forms of flexible dead load support, with little or no lateral restraint. Where adequate clearance with equipment is not provided, potential impact interaction may result. The integrity of the piping is typically not a concern. (Threaded fittings, cast iron pipes and fittings, and grooved type couplings may be exceptions where large anchor movement is possible.) In general, impacts between distribution systems (piping, conduit, ducts, raceways) and equipment of comparable size are not a cause for concern; the potential for large relative motions between dissimilar size systems should be carefully evaluated to assure that a large system cannot carry away a smaller one.

Judgment should be exercised by the SCEs in estimating potential motions of distribution systems in proximity to the equipment under evaluation. For screening purposes, a clearance of 2 inches for relatively rigid cable tray and conduit raceway systems and 6 inches for relatively flexible systems would normally be adequate to prevent impacts, subject to the judgment of the SCEs.

Where potential interaction may involve systems with significant thermal movements during facility normal operating conditions, the thermal displacements should be evaluated along with those resulting from seismic deflections. Inter-equipment displacement limits may be developed from the applicable floor response spectra to assist in this effort. In-structure response spectra (IRS) are discussed in Chapter 5.

7.2.1.2 Mechanical and Electrical Equipment Deflections[4]

Inadequately anchored or inadequately braced mechanical and electrical equipment, such as pumps, valves, vessels, cabinets, and switchgear, may deflect or overturn during seismic loading which results in impact with nearby equipment on the SEL. Certain items, such as tanks with high height-to-diameter aspect ratios, can deflect and impact nearby equipment. Electrical cabinets in proximity to each other may pound against each other or against walls and columns. Suspended equipment components such as room heaters and air conditioning units may impact with equipment.

The SCEs should use judgment in such cases to evaluate the potential displacements and their potential effect on nearby equipment being evaluated. Cabinets with essential relays warrant special concern.

7.2.2 Structural Failure and Falling[5]

Equipment listed on the SEL can be damaged and unable to accomplish its function due to impact caused by failure of overhead or adjacent equipment, systems, or structures. This interaction

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[3] Based on Section D.2.1 of SQUG GIP (Ref. 1)

[4] Based on Section D.2.2 of SQUG GIP (Ref. 1)

[5] Based on Sections D.3 and D.6 of SQUG GIP (Ref. 1)

hazard is commonly referred to as a Category II over Category I concern. This seismic interaction effect can occur from nearby or overhead: (1) mechanical and electrical equipment; (2) piping, raceway, and HVAC systems; (3) architectural features; and (4) operations, maintenance, and safety equipment. The seismic interaction effects which are of concern for these types of equipment, systems, and structures are described below. It is the intent of this evaluation that realistic hazards be identified and corrected; failure of non-seismically supported equipment and systems located over equipment being evaluated should not be arbitrarily assumed.

Facility operations, safety, and maintenance equipment as well as facility architectural features are commonly overlooked in seismic design programs and present sources of seismic interaction concerns. Examples of potential seismic interaction due to failure and falling include the following:

- Partition walls and unreinforced masonry block walls
- Ceiling tiles on unrestrained T-bar grid systems
- Overhead walkway platform grating lacking tie-downs
- Suspended light fixtures and fluorescent tubes
- Storage cabinets, files, and bookcases
- Tool carts on wheels and tool chests
- Ladders and scaffolding
- Portable testing equipment
- Unrestrained gas bottles and fire extinguishers
- Unrestrained equipment on wall-mounted supports
- Unreinforced masonry walls adjacent to equipment may spall or fall and impact equipment or cause loss of support of equipment
- Emergency lighting units and batteries used for emergency lighting can fall or overturn and damage equipment by impact or spilling of acid
- Fire extinguishers may fall and impact or roll into equipment
- Intercom speakers can fall and impact equipment
- Cable trays, conduit systems, and HVAC systems, including HVAC louvers and diffusers, may fall and impact equipment
- Structures or structural elements may deform or fall and impact equipment
- Architectural features such as suspended ceilings, ceiling components such as T-bars and acoustical panels, light fixtures, fluorescent tubes, partition walls, and plate glass may deflect, overturn or break and fall and impact equipment
- Grating may slide or fall and impact equipment

The judgment of the SCEs should be used to differentiate between credible and non-credible interaction hazards.

7.2.2.1 Mechanical and Electrical Equipment[6]

Equipment such as tanks, heat exchangers, and electrical cabinets that are inadequately anchored or inadequately braced have historically overturned and/or slid due to earthquake excitation (see Figure 7.2-5). In some cases this has resulted in damage to nearby equipment or systems.

7.2.2.2 Piping, Raceways, and HVAC Systems[7]

Falling of non-seismically designed piping, raceways, and HVAC systems have been observed in very limited numbers during earthquakes. Most commonly reported are falling of inadequately secured louvers and diffusers on lightweight HVAC ducting. Damage to piping systems is less common and usually is limited to component failures which have rarely compromised system structural integrity. Typical damage is attributed to differential motions of systems resulting from movement of unanchored equipment, attachment of systems between buildings, or extremely flexible long runs of unrestrained piping. Very long runs of raceway systems pose a potential falling hazard when the runs are resting on, but not attached to, cantilever supports.

7.2.2.3 Architectural Features[8]

Architectural features include such items as ceilings, light fixtures, platform grating, unreinforced masonry walls, and other structures. The seismic interaction effects for these are described below:

- Ceilings. T-bar suspended tiles, recessed fixtures, and sheet rock are used in some facility areas (such as the control room). Seismic capabilities of these ceilings may be low. The SCEs should check for details that are known to lead to failure such as open hooks, no lateral wire bracing, etc. Section 10.5.2 discusses suspended ceilings.

- Light Fixtures. Normal and emergency light fixtures are used throughout the facility. Fixture designs and anchorage details vary widely. Light fixtures may possess a wide range of seismic capabilities. Pendant-hung fluorescent fixtures and tubes pose the highest risk of failure and damage to sensitive equipment. The SCEs should check for positive anchorage, such as closed hooks and properly twisted wires. Typically this problem is not caused by lack of strength; it is usually due to poor connections. Emergency lighting units and batteries can fall and damage equipment being reviewed due to impact or spillage of acid.

- Platform Gratings. Unrestrained platform gratings and similar personnel access provisions may pose hazards to impact-sensitive equipment or components mounted on them. Some reasonable positive attachment is necessary, if the item can fall.

- Unreinforced Masonry Walls. Unreinforced, masonry block walls should be evaluated for possible failure and potential seismic interaction with equipment being reviewed unless the wall has been seismically qualified. The SCEs should review the documentation for masonry walls to determine which walls have and which walls have not been seismically qualified. Section 10.5.1 discusses the qualification of these types of walls.

- Structures. If equipment being reviewed is located in lower Performance Category structures, then potential structural vulnerabilities of the building should be identified; however, facility structures are typically seismically adequate.

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6 Based on Section D.3.1 of SQUG GIP (Ref. 1)
7 Based on Section D.3.2 of SQUG GIP (Ref. 1)
8 Based on Section D.3.3 of SQUG GIP (Ref. 1)

7.2.2.4 Operations, Maintenance, and Safety Equipment[9]

Facility operations and maintenance require specialized equipment, some of which may be permanently located or stored in locations near safety systems. Some operations, maintenance, and safety equipment is designed so that it may be easily relocated by facility personnel. Where equipment design or facility operating procedures do not consider anchorage for permanently located equipment, this equipment may slide, fall, overturn, or impact with equipment listed on the SEL. Typically such equipment includes:

- Cabinets and Lockers. Inadequately restrained floor and wall-mounted filing cabinets and equipment storage lockers may result in overturning or falling and impact.

- Gas Storage Bottles. Unrestrained or inadequately restrained gas bottles may result in overturning and/or rolling and this may cause impact. In addition, the gas bottles can become high velocity projectiles if the reducing valve is snapped off and the gas bottles overturn and/or roll. Section 10.3.2 discusses further considerations for gas bottles.

- Refueling Equipment. Refueling equipment such as lifting equipment and servicing and refueling tools may be stored in proximity to equipment being evaluated. Inadequately restrained equipment may pose hazards.

- Monorails, Hoists, and Cranes. Monorails and service cranes are permanently located over heavy equipment requiring movement for service. Falling of service crane components such as tool and equipment boxes may result from inadequate component anchorage. They should be restrained from falling. Judgment by the SCEs should be used to assess the potential for and consequences of such equipment falling.

- Radiation Shields, Fire Protection and Miscellaneous Equipment. Temporary and permanent radiation shielding may pose hazards. Miscellaneous maintenance tools, such as chains and dollies, test equipment, fire protection equipment, fire extinguishers, and hose reels may fall if inadequately restrained. Equipment carts may roll into equipment being evaluated.

7.2.3 Flexibility of Attached Lines and Differential Displacements[10]

Distribution lines, such as small bore piping, tubing, conduit, or cable, which are connected to equipment can potentially fail if there is insufficient flexibility to accommodate relative motion between the equipment and the adjacent equipment or structures. Straight, in-line connections in particular are prone to failure. The scope of review for flexibility of these lines extends from the item of equipment being evaluated to their supports on the building or nearby structure. In addition, the review should consider operational concerns for the lines, such as the relationship of the lines to any check valve and sources of supply for the lines.

Distribution systems that span between different structural systems need to have sufficient flexibility to accommodate differential motion of the supporting structures (see Figure 7.2-6). Piping may be vulnerable where it interfaces with a building structure foundation.

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[9] Based on Section D.3.4 of SQUG GIP (Ref. 1)
[10] Based on Sections D.4 and D.6 of SQUG GIP (Ref. 1)

Examples of potential seismic interaction due to flexibility of attached lines include the following:

- Piping, cable trays, conduit, and HVAC may deflect and impact equipment
- Anchor movement may cause breaks in piping, cable trays, conduit, HVAC, etc. which may fall or deflect and impact adjacent equipment

The judgment of the SCEs should be used to differentiate between credible and non-credible interaction hazards.

7.2.4 Water Spray, Flood, and Fire Hazards

Potential seismic-induced spray, flood, and fire interaction sources should be evaluated and a few examples include the following:

- Hazardous/flammable material stored in unanchored drums, unanchored shelves, or unlocked cabinets
- Nonductile fluid-carrying pipe (such as cast-iron or PVC pipe) (see Figure 7.2-7)
- Fire protection piping with inadequate clearance around fusible-link sprinkler heads (see Figure 7.2-8)
- Natural gas lines and their attachment to equipment or buildings
- Acetylene bottles
- Mechanical and threaded piping couplings can fail and lead to pipe deflection or falling and impact on equipment. Grooved type couplings used in fire protection piping are one example of this type of mechanical coupling
- Sheetrock may fall and impact equipment if it was previously water-damaged or if there is severe distortion of the building
- Unanchored room heaters, air conditioning units, sinks, and water fountains may fall or slide into equipment

The judgment of the SCEs should be used to differentiate between credible and non-credible interaction hazards.

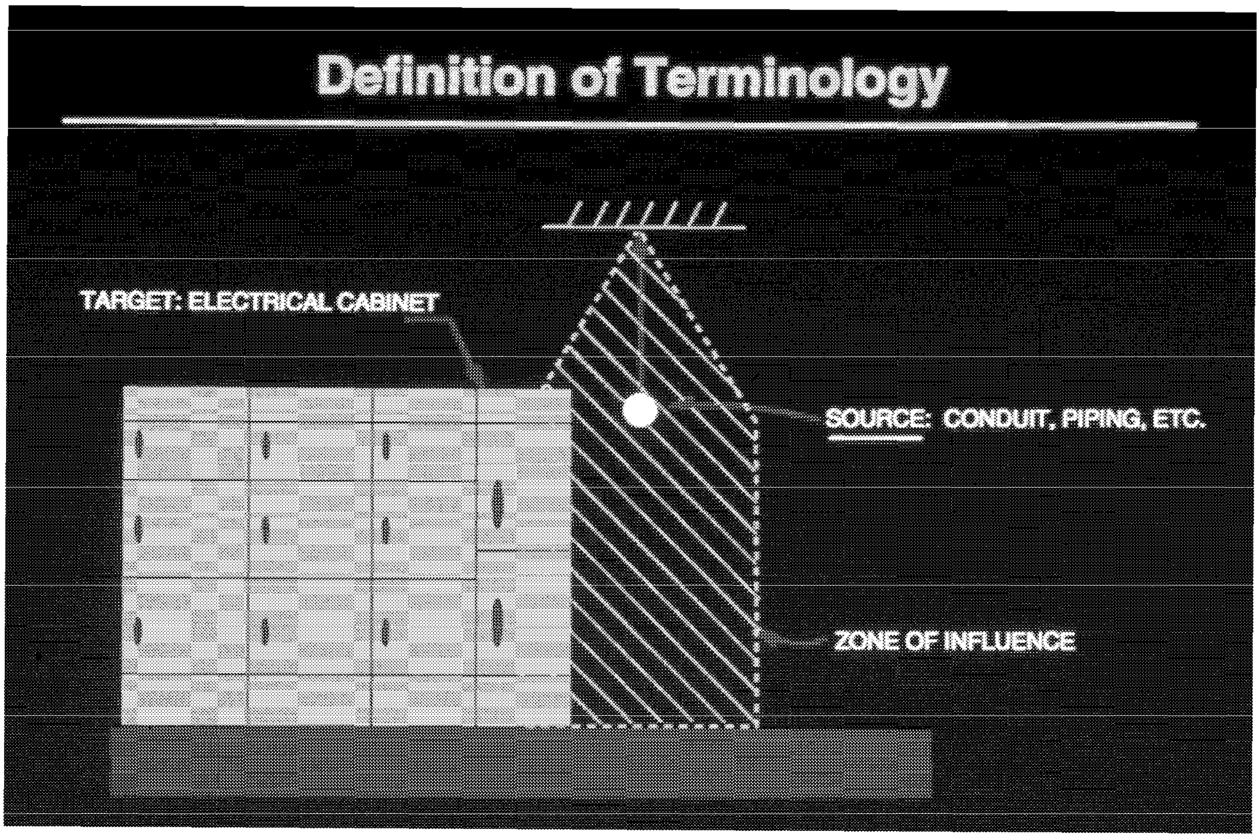

Figure 7.2-1 Example of Seismic Interaction

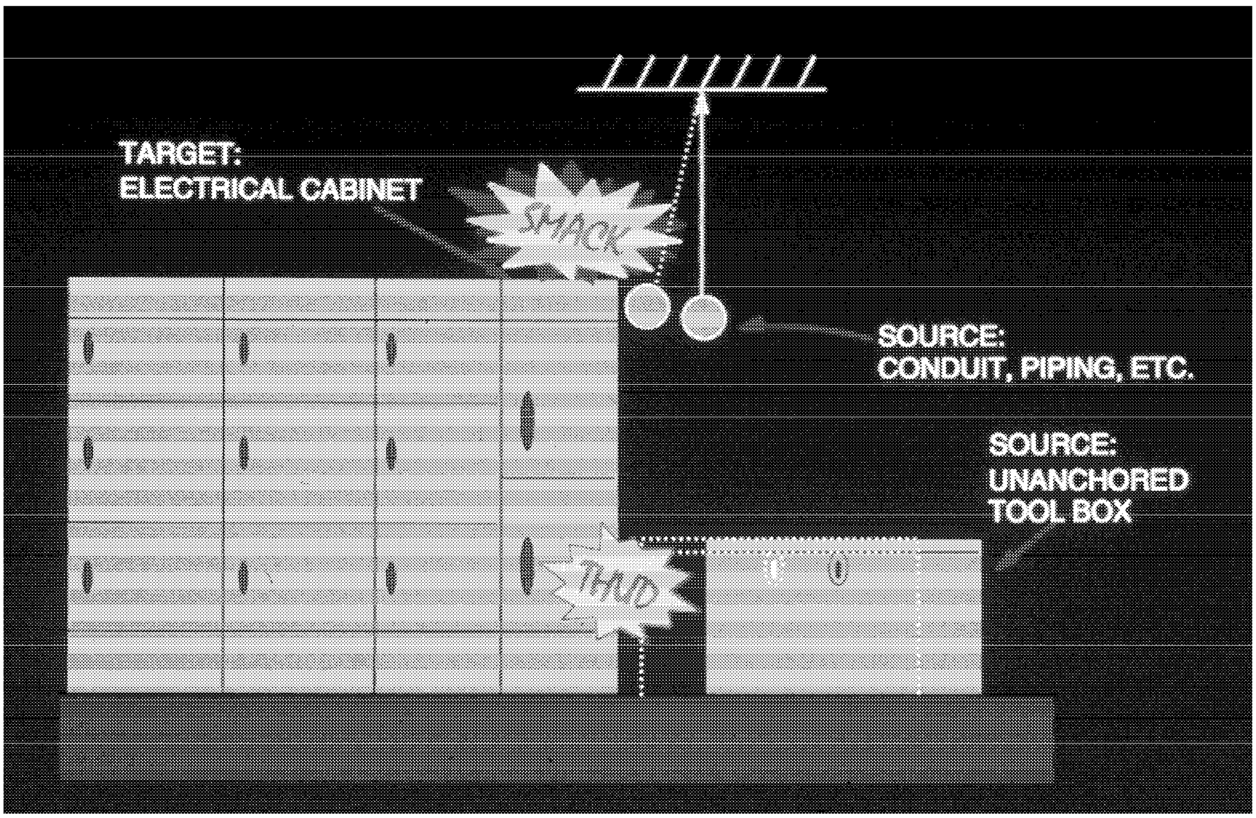

Figure 7.2-2 Example of Credible Interactions

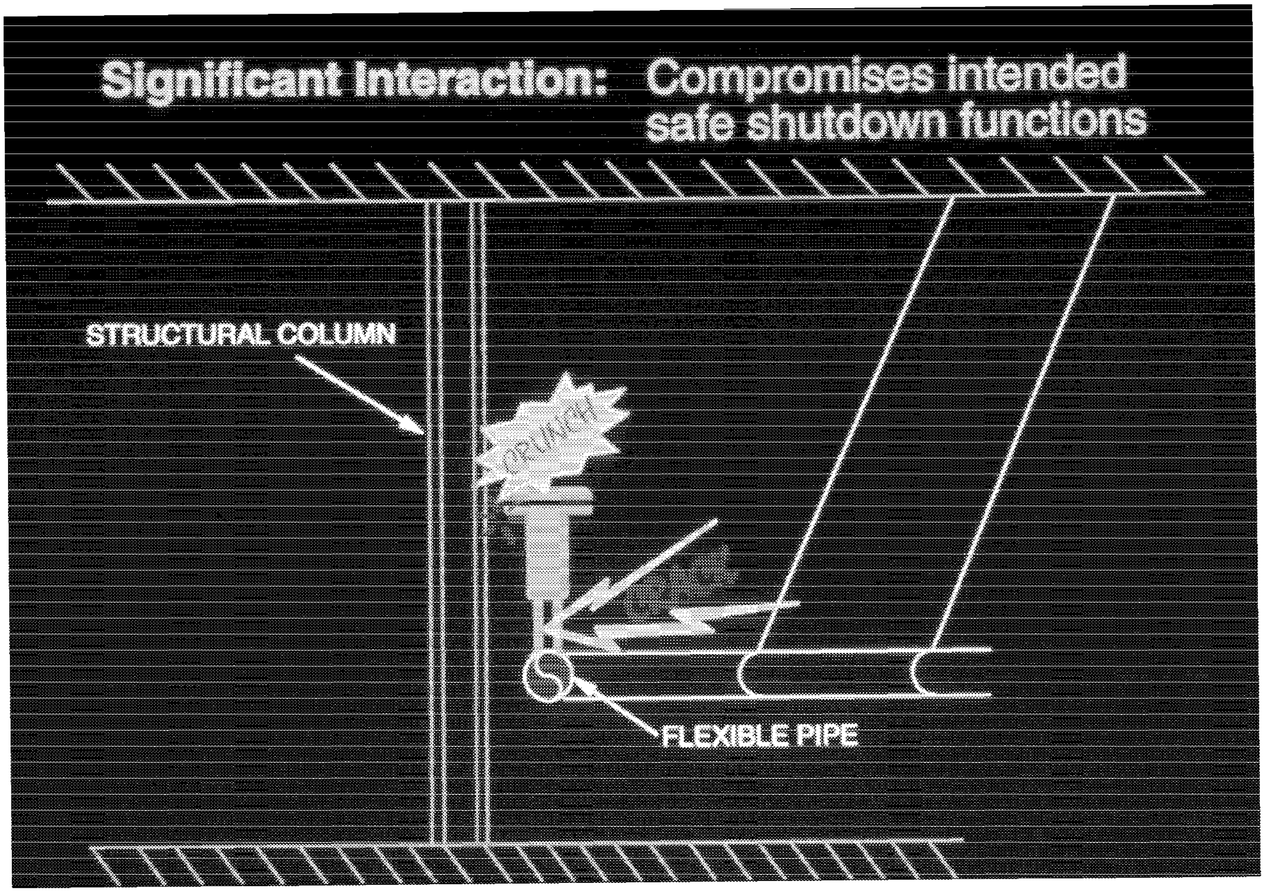

Figure 7.2-3 Example of Significant Interaction which Compromises Intended Safety Functions

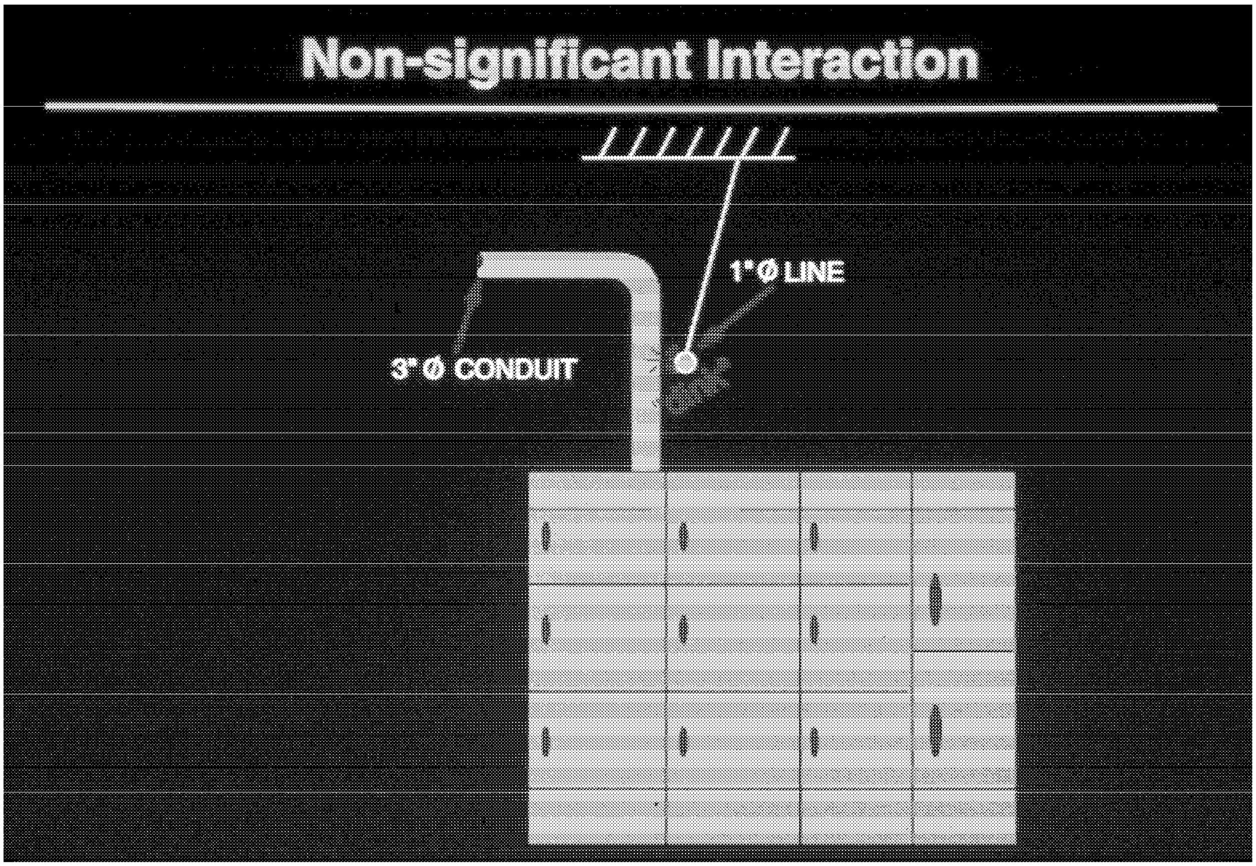

Figure 7.2-4 Example of Non-Significant Interaction

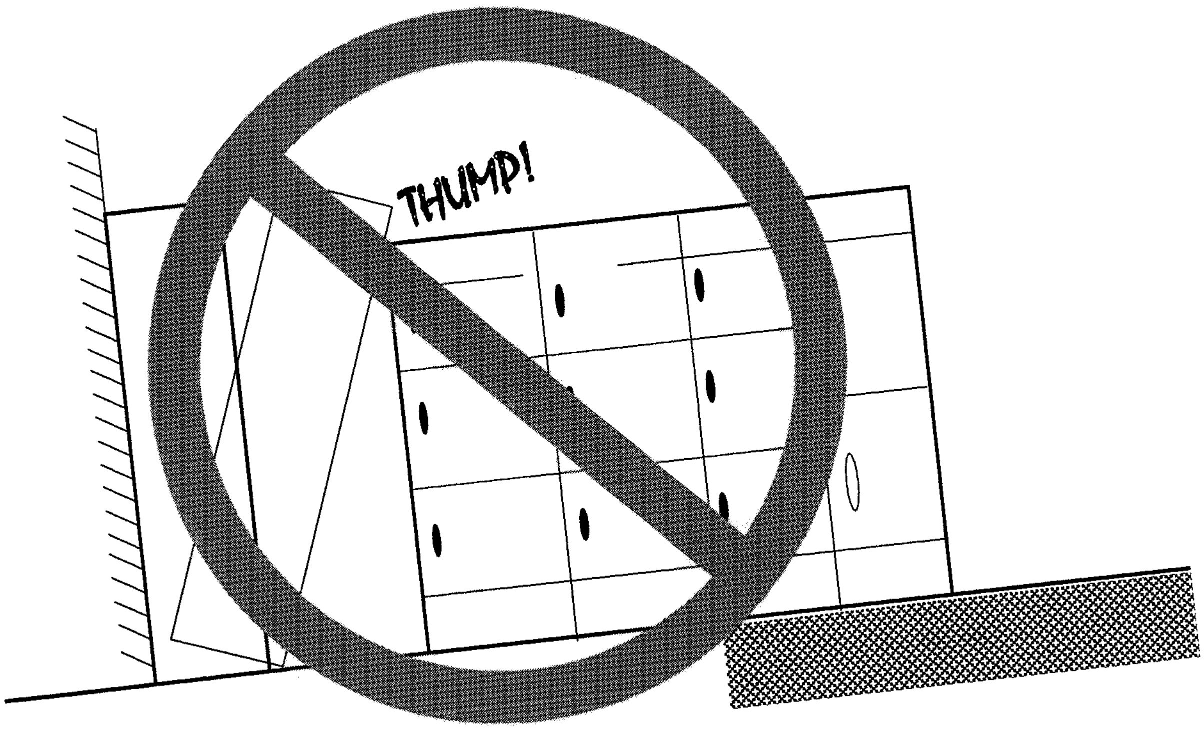

Figure 7.2-5 Failure and Falling Interaction Hazards

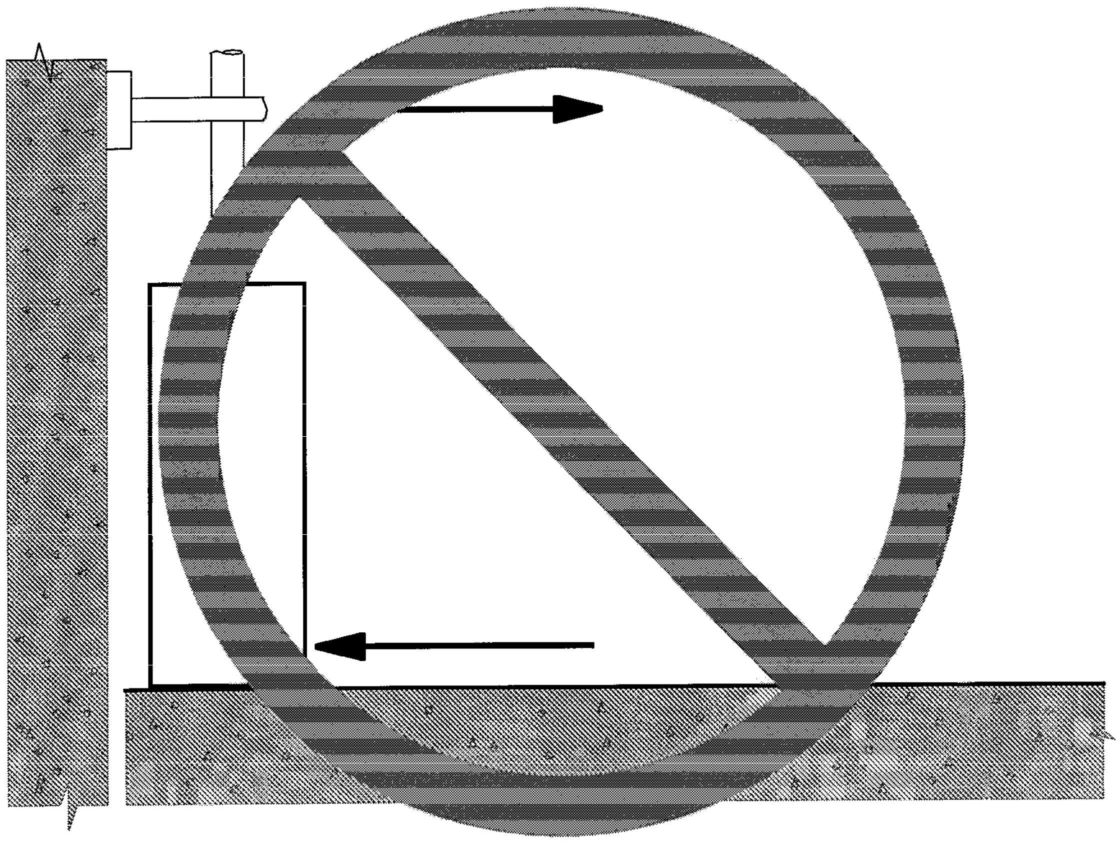

Figure 7.2-6 Differential Displacement Interaction

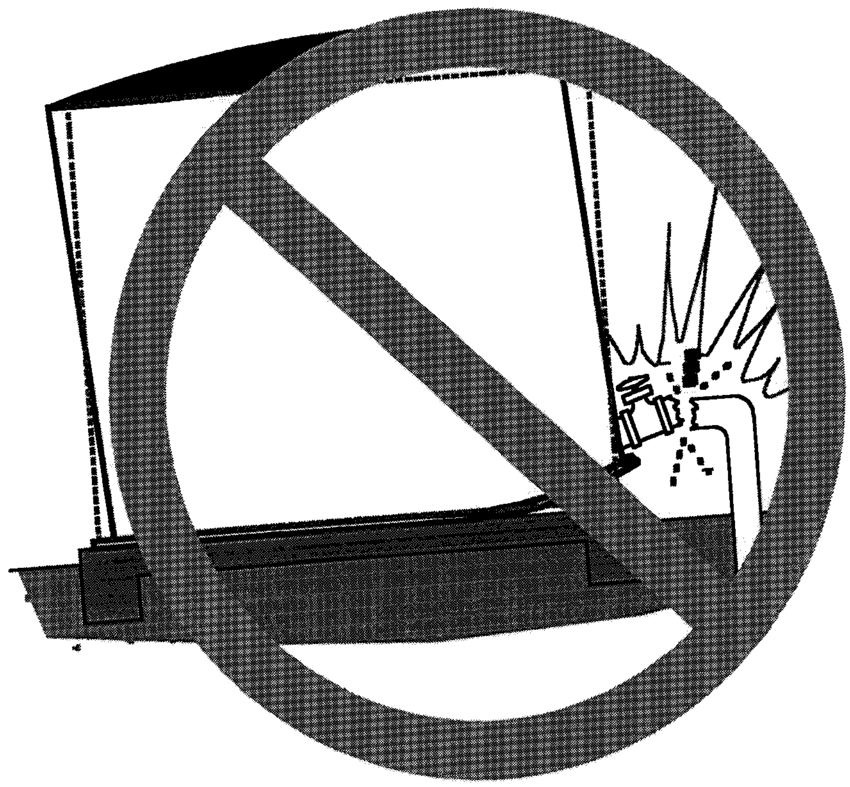

Figure 7.2-7 Pipe Break Potential for Unanchored Tanks

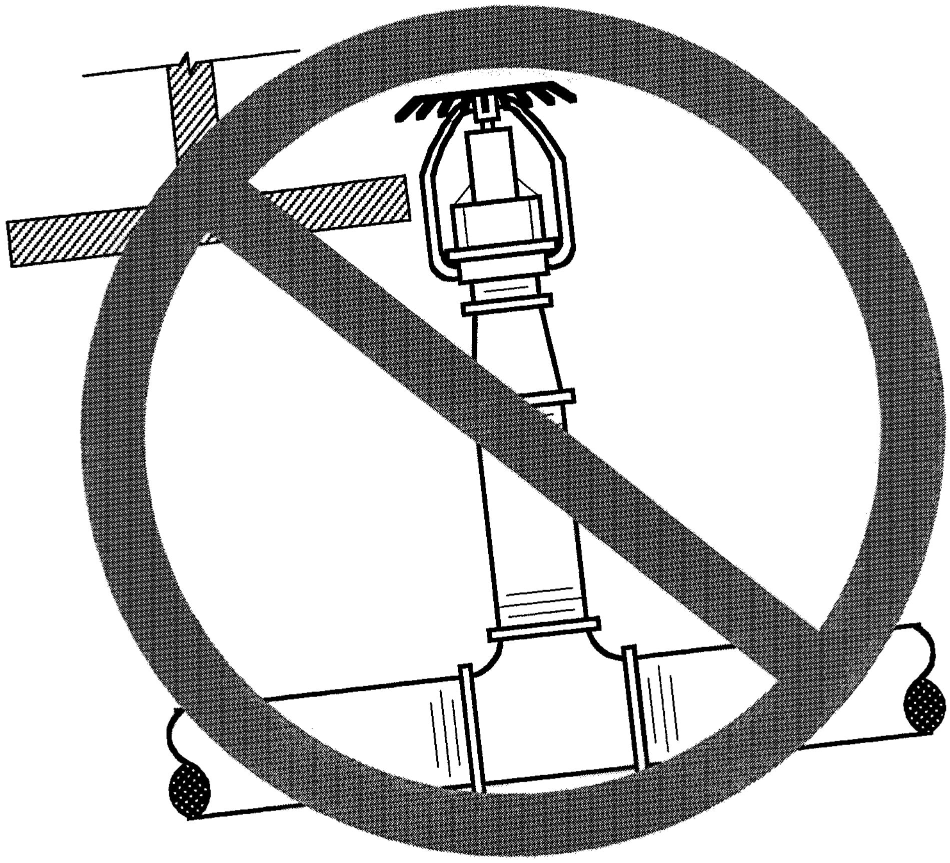

Figure 7.2-8 Fusible link sprinkler heads are sensitive to impact.

7.3 DOE GUIDANCE

Guidance on the treatment of seismic interaction effects is included in DOE-STD-1021, "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components" (Ref. 7). This guidance focuses on "two over one" concerns and should be used to evaluate the seismic interaction effects discussed in Section 7.2. "Two over one" concerns, as discussed in DOE-STD-1021 and DOE-STD-3009 (Ref. 11), are those with a lower safety class structure, system, or component (SSC) located above, or able to interact with, a higher safety class SSC. Further detailed information on selecting performance and hazard categories is provided in References 7, 10, and 11.

7.3.1 System Interaction Effects[11]

(a) An SSC that has been preliminary categorized in accordance with the basic performance categorization (PC) guidelines of Section 2.4 of Reference 7 (the source) shall have appropriate additional seismic mitigation requirements as provided in Paragraphs (b), (c) and (d) below, if its behavior by itself, or the multiple common-cause behavior of it with other SSCs may adversely affect the performance of other SSC (the target). These additional requirements will depend on the type of source behavior that causes adverse interaction with the target during or following an seismic event.

(b) If the source behavior that causes adverse interaction is within the acceptable behavior limits of the source (i.e., if the adverse interaction occurs before failure) adequate measures shall be taken to preclude such interaction and to ensure that the performance goal for the target is preserved. For example, assume that the postulated seismic deflection of a performance category (PC)-1 cabinet (source) is within its own acceptable behavior limits, but the cabinet can potentially impact and fail a PC-2 fire-suppression component (target). To prevent this adverse interaction, the cabinet support system or the cabinet itself can be stiffened/strengthened in such a way that the calculated deflection of the cabinet towards the target, when subjected to a seismic level corresponding to the performance category of the target, is less than the available clearance by a factor equal to the applicable design margin for the target. Alternatively, a barrier can be provided to preclude the adverse interaction and to protect the target. Such a barrier shall be designed to withstand seismic effects combined with the interaction effects from the source (in this case the impact from the PC-1 cabinet). To ensure that the target performance goal is preserved, the barrier shall be placed in the same performance category as the target (in this case PC-2).

(c) If the adverse interaction is possible only after the source fails or exceeds its acceptable behavior limits, either of the following two requirements shall be met to preclude adverse interaction:

(i) The source shall have additional seismic requirements corresponding to the performance category of the target, if the failure probability of the target, given the failure of the source, is greater than one percent. If the implementation of this criteria is judged not to be cost-effective, the additional seismic mitigation requirements for the source shall be in accordance with Table 7.3-1. In either case, these additional requirements can be restricted to the source failure mode related to the adverse interaction effects.

(ii) Adequate measures shall be taken to preclude adverse interaction and to ensure that the performance goal for the target is preserved. Examples of acceptable measures

[11] Based on Section 2.5 of DOE-STD-1021 (Ref. 7)

Table 7.3-1 System Interaction Effects on Performance Categorization (Reference 7)

Performance Category of Target SSC[1]	Preliminary Performance Category of Source SSC[2]	Range or Limit of Target Failure Probability Due to Interaction[3] (p)	Revised NPH Requirements of Source SSC[4]
PC-4	PC-3	p > 10%	PC-4
		p ≤ 10%	PC-3[5]
	PC-2	p > 10%	PC-4
		1% < p ≤ 10%	PC-3
		p ≤ 1%	PC-2[5]
	PC-1	p > 10%	PC-4
		1% < p ≤ 10%	PC-3
		p ≤ 1%	PC-1[5]
PC-3	PC-2	p > 10%	PC-3
		p ≤ 10%	PC-2[5]
	PC-1	p > 10%	PC-3
		p ≤ 10%	PC-1[5]
PC-2	PC-1	p > 10%	PC-2
		p ≤ 10%	PC-1[5]

SSC - Structure, System, or Component
NPH - Natural Phenomena Hazard
PC - Performance Category

Notes:

(1) If the target consists of more than one SSC, the highest performance category of the group shall be considered here.

(2) This is the preliminary performance category of the source SSC before considering system interaction effects. Note that PC-0 is not considered here because a PC-0 SSC cannot have any adverse effect on the performance of PC-1 through PC-4 SSCs

(3) This is the approximate probability of exceedance of acceptable behavior limit for the target SSC given that the source SSC will fail and interact with target SSC due to NPH effects.

Thus, if the target is a PC-4 SSC that may be adversely affected by the failure of a PC-2 SSC (source), and if the target failure probability due to this interaction is greater than 10%, then one of the methods of precluding the interaction will be to subject the source to additional NPH requirements corresponding to PC-4 (see also note 4 below).

(4) The source SSC shall be designed/evaluated to those requirements of the revised performance category that are essential for precluding adverse interaction with the target (in other words, it is not necessary to satisfy the functional requirements of the source SSC when subjected to these additional NPH requirements unless essential for precluding adverse interaction).

The basis for determining the revised NPH requirements for the source SSC is that the performance goal of the target SSC shall not be compromised because of system interaction effects, i.e. the product of the performance goal for the revised source performance category and the target failure probability must not be more than the performance goal of the target SSC. However, to account for uncertainties in determining target failure probabilities, the limiting values in the 3rd column of the table have been selected conservatively (i.e. lower than the values computed on the above basis).

(5) For these cases, consideration of interaction effects does not require additional NPH requirements for the source SSC.

are: stiffening/strengthening of the source structure or support system, relocating the source and/or the target, installing barriers, installing new components, modifying existing components, or any combination of these measures.

(d) If the behavior or failure of a source can adversely affect the performance of more than one target, the source shall have additional seismic requirements corresponding to the highest performance category that is determined by applying the rules provided in Paragraphs (a), (b), and (c) above separately for each target.

7.3.2 Determination of System-Interaction-Related Target Failure Probability[12]

To account for adverse system interaction, the determination of failure probability of the target component given the failure of the source component is required. Depending on the physical and functional complexity of the target and the nature of its interaction with the source, the level of effort in determining this target failure probability can vary. Following the" graded approach" philosophy, the level of rigor with which such failure probabilities are to be determined should depend on the safety significance and the preliminary performance category of the target, the hazard category of the facility, and the relative cost of various methods of determining target failure probabilities.

In the following paragraphs two methods of determining or estimating target failure probabilities are presented in order of decreasing rigor.

(a) Systematic Analysis Method

Target failure probabilities can be determined using a systematic analysis approach by constructing a fault-tree of the scenario. If justifiable from cost-benefit considerations, this may be a desirable method when necessary data is available. Generally, it should be used when the failure of the target is dependent on a large and complex chain of events that may follow the failure of the source, or to qualify a large system in its entirety. Component-by-component application of this method is unlikely to be cost-effective.

(b) Approximate Method

In this method, the effects of source failure on target are modeled approximately, but rationally, considering possible scenarios identified by review of system design. Even though such models are approximate, their analyses provide good "order-of magnitude" type of data that are often adequate for the purpose. Examples of the use of this method are given in Section 7.3.4.

7.3.3 Application of System Interaction Rules[13]

The consideration of adverse effects of system interaction of one component or system (source) on the other (target) is very important in determining performance categories of SSCs. Adverse interaction effects can be different for different systems. Examples of common adverse interaction effects are:

(i) Structural Failure and Falling (see Section 7.2.2): Inadequately designed, inadequately anchored, and unanchored components may fail, slide, and/or topple and fall on or bump into other components that are not designed to withstand such interaction effects.

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[12] Based on Section 3.8 of DOE-STD-1021 (Ref. 7)
[13] Based on Section 3.9 of DOE-STD-1021 (Ref. 7)

(ii) Proximity and Impact (see Section 7.2.1): Adjacent components may impact each other causing damage if the clearance between them is inadequate for seismic - induced deflections. Such adverse interaction may occur even if the deflection of the source is within its design limits.

(iii) Differential Displacement (see Section 7.2.3): A target distribution system (e.g., vital cable trays, pipes, ventilation ducts) may span between different structural systems (source). Differential displacement may be within acceptable behavior limits for the individual structures, but may still affect the distribution systems adversely.

(iv) Mechanical or Electrical Failure (see Section 7.2.4): The failure of a source mechanical or electrical component may impair the safety function of another component or system (e.g., the failure of a valve in a non-safety water distribution system causing flooding that short-circuits a safety class electrical motor).

Paragraph (b) of Section 7.3.1 provides the general requirements for precluding interaction that can occur before the source fails or reaches its acceptable behavior limits. Paragraph (c) of Section 7.3.1 provides three options to meet the requirements for precluding adverse interaction that can occur only when the source fails. The following paragraphs provide additional discussions on these three options:

(a) The first guideline in Paragraph (c)(i) of Section 7.3.1 is the most conservative of the three options, because it requires additional seismic requirements if the failure probability of the target exceeds only 1%. But it can also be most costly, since it may require upgrading the SSC. Hence, this guideline should be used when:

    (i) upgrading of the source does not involve a significant design change, or

    (ii) the existing source design has an adequate margin to withstand the same seismic level as the target.

(b) The second option in Paragraph (c)(i) of Section 7.3.1 requires the determination of target failure probability values, and depending on these values, the source may or may not need to be subjected to additional seismic requirements (see Table 7.3-1).

    This guideline should be used if the application of conservative "one-percent" rule cannot be justified from cost-benefit considerations. For example, if it is determined that the application of the "one percent" rule will require a PC-1 source to have seismic requirements equivalent to a PC-4 SSC resulting in expensive design changes, the use of Table 7.3-1 should be considered to reduce unnecessary conservatism.

(c) The third option given in Paragraph (c)(ii) of Section 7.3.1 requires the use of a barrier to prevent the source from interacting with the potential target. Very often this can be the most practical and cost-effective option. The barrier must be placed in the same performance category as the target, and be designed to withstand the interaction effects from the source in addition to the seismic loads.

7.3.4 Examples of Categorization Using System Interaction Rules[14]

This subsection provides few examples of the application of categorization rules considering system interaction effects as provided in Section 7.3.1.

(a) Example 1

Consider an emergency diesel generator in a Hazard Category 2 facility that is classified as a safety system using appropriate DOE orders and general design criteria. The diesel, generator, and all their support systems (e.g., fuel, lubrication, cooling water, and DC power systems) that perform a safety function should be evaluated as PC-3 in accordance with the provisions of Section 2 of Reference 7.

Consider the fluorescent light (source) hung directly above the diesel. For this case, assume that the light is not needed for required operator actions following a seismic event. Hence its preliminary performance category is PC-1. Diesels themselves are fairly rugged, and a falling lightweight object, like the light fixture is unlikely to damage them. However, there are some possible weak spots, particularly in the peripheral support systems (e.g., lubrication lines) that might be damaged and result in system failure. Assume that, in accordance with Section 3.8 of Reference 7, the failure probability of the diesel resulting from the falling light fixture is estimated to be approximately 25%. (This probability assumes the lighting fixture will fall. No credit is given at this stage for its design.) Following Paragraph (c)(ii) of Section 7.3.1, the lightning fixture should then be placed in PC-3.

(b) Example 2

Consider a case in which batteries for an uninterruptible power supply (UPS) in a Hazard Category 3 facility are in the same room with a 2000-gallon water storage tank. The UPS is classified as a safety system but the water storage tank is not. The UPS batteries (and their rack, connections, and the surrounding room structure) should be evaluated as PC-2 in accordance with the provisions of Section 2 of Reference 7.

Initially, the water storage tank might be considered as PC-1 (i.e., preliminary performance category). However, a systems-interaction check discloses that UPS batteries will short out during water immersion if only 1000 gallons of water flood the room. Thus, in accordance with criterion given in Paragraph (a)(i) of Section 7.3.1, the 2000-gallon tank should have the same performance category as the UPS batteries, that is, PC-2.

But what if the water was stored instead in ten 200-gallon tanks? The individual failure of each tank would not fail the UPS. However, if "multiple common-cause failure" is considered, one could reason that all ten tanks would be affected in the same way by the seismic event and simultaneous failure of several tanks might occur, leading to flooding of the batteries. Thus, each 200-gallon tank should also be placed in PC-2 in accordance with the provisions of Section 2 of Reference 7.

(c) Example 3

Consider a 100-foot-tall smoke stack for a laundry building at a DOE site that is not part of any safety system. However, its failure (from winds or earthquakes) would be costly and could injure workers, so initially it would be classified as Preliminary PC-1. Consider that there is a single Hazard Category (HC) 3 safety system component (say a PC-2 outside pump) that is 90 feet from

[14] Based on Section 3.10 of DOE-STD-1021 (Ref. 7)

the base of the stack. A systems interaction analysis may assume that the stack would fall in essentially one piece and would fail the pump if it hits it. But the stack is equally probable to fall in any radial direction and the target size of the pump is small, fitting into a 2 degree angle. It is concluded that the probability of the stack hitting the component is less than 1%. Thus in accordance with Paragraph c(ii) of Section 7.3.1, the stack can be retained in PC-1.

(d) <u>Example 4</u>

Consider a Hazard Category 1 facility that relies heavily on operator actions, rather than seismically-qualified instrumentation and automatic control systems, to maintain a safe-state following a design basis earthquake. According to Section 2 of Reference 7, safety system SSCs of this facility should be placed in PC-4. In addition, SSCs needed to permit required operator actions following a design basis earthquake must also be classified as PC-4.

As an example, assume that one earthquake procedure written for this facility requires that an operator would go inside the pump room to read a water level gauge (which is seismically-qualified), and then relay this information to the control room via a system of walkie-talkies (assume that inside telephone lines are not seismically qualified). Items needed to permit this action, and thus which must meet PC-4 criteria, include all access doors (deformation of the door frames may be critical), emergency lightning and communication systems (the storage of flashlights and walkie-talkies could become a seismic design consideration), and any water or steam line whose seismic failure would be hazardous to the operator.

7.4 EVALUATION OF INTERACTION EFFECTS[15]

The SCEs should identify and evaluate all credible and significant interactions in the immediate vicinity of the equipment listed on the SEL. This includes consideration of seismic interactions on the equipment itself and on any connected distribution lines (e.g., instrument air lines, electrical cable, and instrumentation cabling) which are in the vicinity of the item of equipment. Evaluation of interaction effects should consider detrimental effects on the capability of equipment and systems to function; taking into account equipment attributes such as mass, size, support configuration, and material hardness in conjunction with the physical relationships of interacting equipment, systems, and structures. In the evaluation of proximity effects and overhead or adjacent equipment failure and interactions, the effects of intervening structures and equipment which would preclude impact should be considered. The effects of fire, flooding or exposure to fluids from ruptured vessels and piping should also be examined.

As summarized in this chapter, the considerations for seismic interaction effects include the following:

1. Soft targets free from impact by nearby equipment or structures.

2. If equipment contains sensitive essential relays, equipment free from all impact by nearby equipment or structures.

3. Attached lines have adequate flexibility.

4. No collapse of overhead equipment, distribution systems, or masonry walls.

5. Equipment is free from credible and significant seismic-induced flood and spray concerns.

[15] Based on Section D.5 of SQUG GIP (Ref. 1)

6. No credible seismic-induced fire concerns.

7. No other "two over one" concerns as defined in DOE-STD-1021.

8. No other concerns.

Good housekeeping within a facility can prevent many possible sources of seismic interaction. Miscellaneous equipment or supplies such as carts, ladders, brooms, and dollies can be easily stored such that they do not become sources of seismic interaction. In addition, the general arrangement of the facility and its contents can be developed to accommodate clearances and "stay-out" zones for the equipment being evaluated.

Damage from interaction in earthquakes is from unusual circumstances or from generic, simple details such as open hooks on suspended lights. The SCEs should spend most of their time evaluating: 1) unusual impact situations, and 2) lack of proper anchorage or bracing. The SCEs should not be concerned much with interaction issues due to piping and other system or structural component failures.